Changes in accessibility to food banks and food services during COVID-19 and implications for the food security of vulnerable populations in Hamilton, Ontario

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Abstract

This is the abstract.
    It consists of two paragraphs.

CRediT author statement

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Introduction

Food insecurity is defined as an "inadequate or uncertain access to a sufficient quantity and/or adequate quality of food" due to a household's financial limitations (Enns et al., 2020). This condition has been associated with reductions in nutritional outcomes (Bhattacharya et al., 2004; Kirkpatrick and Tarasuk, 2008; Olson, 1999) and physical and mental health in children and adults (Elgar et al., 2021; Jones, 2017; Ramsey et al., 2011; Seligman et al., 2010; Stuff et al., 2004). Over at least the past four decades food banks and related services have become an essential line of defense against food insecurity in Canadian communities (Black and Seto, 2020; Holmes et al., 2018; Riches, 2002; Tarasuk et al., 2020). In this respect, Canada is not unlike numerous other wealthy countries where a systematic dismantling of the welfare state took place in the intervening period (Tarasuk et al., 2014).

The emergence of COVID-19, the worst public health crisis since the 1918 flu pandemic, has revealed important social and economic fault lines, and pre-existing patterns of inequality appear to have been exacerbated. Along several other dimensions of stress (e.g., accessibility to health care facilities, Pereira et al., 2021a), this seems to be the case for food insecurity as well (Laborde et al., 2020). In the US, for example, it has been estimated that there was an increase of more than 30% in household food insecurity, and more than one third of households were discovered to be newly food insecure - meaning they did not experience food insecurity before the pandemic (Niles et al., 2020). In Canada, Men and Tarasuk (2021) report that about 25% of individuals who experienced job insecurity (a relatively common occurrence during the pandemic), also experienced food insecurity. Similarly, according to Statistics Canada (2020a), in the early stages of the pandemic almost 15% of individuals reported living in a household that faced food insecurity; the risk of food insecurity was substantially higher for households with children. The difference between households with and without children was significant, and 11.7% of households with children indicated that "food didn't last and [there was] no money to get more" sometimes or often, compared to 7.3% of households without children; likewise, 13% of households with children indicated that they "[c]ouldn't afford balanced meals" sometimes or often, compared to 8.8% of households without children.

The impacts of food insecurity during the pandemic are alarming, since diet-related diseases, such as obesity, heart-disease, and diabetes, were already critical public health concerns in Canada prior to COVID-19 (Boucher et al., 2017). While food banks are not necessarily a stable solution to food insecurity and in fact may encourage a retrenchment of neoliberal policy (Wakefield et al., 2013), at least they can be argued to provide a resource of last instance to households in precarious situations (Bazerghi et al., 2016). As recently as 2019, the Hamilton Hunger Report[1] noted that food banks in Hamilton, Ontario,

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[1] https://www.hamiltonfoodshare.org/wp-content/uploads/Hamilton-Food-Share-Hunger-Report-2019.pdf

recorded the highest number of visitors in the past 29 years; the number of children visiting food banks (minors up to 18 years old) was 9,125 in March 2019, up from 8,278 the year before, a rate of increase greater than population growth.

It is known that urban food environments, within which people make their daily food choices, are essential in influencing eating behaviours and health outcomes, based on factors such as food availability, ease of geographic accessibility and socio-demographic variations (Paez et al., 2010; Vanderlee and L'Abbé, 2017; Widener, 2018). However, while there is a wealth of literature that has examined the topic of geographic accessibility to healthy food through the "food desert" concept, there has been little research into accessibility to food banks. Although previous work has explored differences in *accessing* food banks, such as how some households utilize food banks over short periods of time while others regularly utilize food banks as longer-term resource (e.g., Enns et al., 2020), we are not aware of any research that has focused on the geographic component of accessibility.

The study of place-based geographic accessibility is concerned with capturing the potential to reach destinations of value using the transportation network (Páez et al., 2012). Indeed, the Government of Canada's recent Food Policy has made "access" to healthy food a priority for Canadian communities[2] and previous survey research has suggested that such accessibility plays a key role in user satisfaction with food bank service delivery (Holmes et al., 2018). However, as with research into the prevalence of food deserts, accessibility to food banks is unlikely to be evenly distributed, and variation throughout a city can be expected due to transportation network characteristics, and the spatial distribution of food bank locations and the population they are meant to serve. Furthermore, policy responses to the COVID-19 pandemic likely have added to the distress of vulnerable households. Non-pharmaceutical interventions during the pandemic involving restrictions in mobility have increased the friction of travel, in particular by transit on which low income populations are more reliant (e.g., DeWeese et al., 2020). At the same time, the pandemic has created additional stress for the operators of food banks through disruptions in the supply chain (e.g., McKay et al., 2021) as well as concerns surrounding the delivery of service in safe conditions and possible cancellation of food service programs.

For this study, we aim to look at how the landscape of food banks and related services (e.g. low-cost or free meal service providers) available in Hamilton, Ontario, changed during the pandemic. Did the number of open food bank services diminish? If so, what was the accessibility to food banks before the pandemic from the perspective of low income households, and how it changed during the pandemic? And finally, who are most likely to have been impacted by changes in the accessibility landscape? This paper first looks at the distribution of food banks and related services before and during the pandemic. Then, we

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[2]https://www.agr.gc.ca/eng/about-our-department/key-departmental-initiatives/food-policy/the-food-policy-for-canada/?id=1597863791042

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use the balanced floating catchment area approach of Paez et al. (2019) to investigate the accessibility situation. For this, we use a fully disaggregated approach based on parcel-level data. Socio-economic and demographic data are drawn from the latest Census of Canada (2016), whereas travel information is from the most recent regional travel survey from 2016. This paper follows reproducible research recommendations (see Brunsdon and Comber, 2020), and the research was conducted using open source tools for transportation analysis (Lovelace, 2021). The code and data necessary to reproduce the analysis are available in a public repository[3].

Food Insecurity and Food Bank Use in Canada

Food insecurity is the inability to acquire and consume an adequate amount or good quality food, leading to inadequate nutrient intake (Enns et al., 2020; Kirkpatrick and Tarasuk, 2008; Tarasuk and Vogt, 2009). This nutrient deficiency is associated with major population health concerns, particularly among Canadians at socio-economic disadvantage (Bazerghi et al., 2016). Data on food insecurity in Canada is collected in several ways. Quantitatively, official government surveys such as the Household Food Security Survey Module (HFSSM), the Canadian Community Health Surveys (CCHS), the International Study of Adults (LISA), and official classifications determined by Health Canada in relation to socio-demographic variables offer some insight into food insecurity (Gundersen et al., 2018; Kirkpatrick and Tarasuk, 2008; Tarasuk and Vogt, 2009). Nationally, it has been found that food insecurity impacts approximately 12.3% of Canadian households (Tarasuk et al., 2014)

Food banks - sometimes also referred to as 'food pantries' and 'food shelves' - originated as a community response to aid those with inadequate food by voluntarily offering them meals and ingredients (Loopstra and Tarasuk, 2012; Riches, 2002). The scope and objectives of food banks can vary by region and by country, and these organizations can include not only prepared meals and aliments, but also shared spaces to connect in community gardens and community kitchens (Wakefield et al., 2013). Although in their origin food banks were meant to be provide a temporary solution to accommodate those in hunger due to job retrenchments and economic downfalls since the 1980s, over time they have evolved into a community practice to secure emergency food supplies for those in need (Loopstra and Tarasuk, 2012; Wakefield et al., 2013).

In Canada, the number of food banks has steadily increased in the past few decades (Wakefield et al., 2013). The largest database of food banks and their use comes from the non-profit association Food Banks Canada (FBC), which conducts an annual assessment through its affiliated members. FBC's 2018 Hunger Count report[4] (the most recent available) listed 1,830 member

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[3]add repository

[4]https://foodbankscanada.ca/getmedia/241fb659-05f5-44a2-9cef-56f5f51db523/HungerCount-2018_FINAL_EN.pdf.aspx?ext=.pdf

food banks across the country, and found that Canadians visited food banks 1.1 million times in March of 2018. Of those accessing food banks, certain population characteristics tend to be over-represented compared to national totals from the 2016 Canadian Census of Population. According to FBC's 2018 data, single-adult households represent 45% of those utilizing food banks despite making up 28% of Canada's population, 19% are single-parent households (compared to 10% nationally), and 35% of those accessing food bank services are children aged 0-18 even though their share of Canada's national population is approximately 20%. In addition, 59% of households accessing food banks list social or disability assistance as their primary source of income. Similarly, using data from the 2011-2012 CCHS, Tarasuk et al. (2019) found higher odds of food insecurity amongst households relying on social assistance, those without a university degree or with children under the age of 18, and individuals that lived alone, renters, and those identifying as Aboriginal. While surveys revealed that only 20 to 30 percent of those experiencing food insecurity were found to frequent food banks in Canada (Tarasuk et al., 2014), research from Ottawa (Enns et al., 2020) and Vancouver (Black and Seto, 2020) suggests that long-term users tend to be older, have health or mobility challenges, live in large households, and are less likely to have employment income.

Economic stress caused by the COVID-19 pandemic, rising unemployment rates, and changes in poverty levels have disrupted the food environment and led to higher rates of food insecurity (Niles et al., 2020). Pandemic-related food security studies in the US have found a substantial increase in households experiencing food insecurity for the first time, and also in households experiencing more severe food insecurity than before (Niles et al., 2020; Wolfson and Leung, 2020). Most recently in May 2020, Canada recorded 14.7% of its population living in food insecurity in the past 30 days (Statistics Canada, 2020a). Considering the negative mental and physical health effects associated with food insecurity, increases in food insecurity rates due to the pandemic, signal a change in the food environment with potential damages to population health during the course of the pandemic and beyond (Niles et al., 2020). Recent data[5] from FBC showed that 52% of member food banks reported an increase in usage in March of 2020 when initial lockdown restrictions were put in place across much of the country. The pandemic also created significant staffing issues with 42% of food banks reporting a reduction in volunteers. However, 53% of food banks later reported a decrease in use into the summer of 2020 which FBC members attributed to emergency financial support programs from the federal government. Nevertheless, some of these benefit programs were temporary, which suggests that many households may again turn to food bank services to meet their needs.

In terms of geography, previous research conducted at the provincial scale using data from the 2011-2012 CCHS found that the prevalence of food insecurity ranged across the country from 11.8% of households in Ontario to 41% of

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[5]https://www.foodbankscanada.ca/FoodBanks/MediaLibrary/COVID-Report_2020/A-Snapshot-of-Food-Banks-in-Canada-and-the-COVID-19-Crisis_Exec-Sum_EN.pdf

households in Nunavut (Tarasuk et al., 2019). However, although previous research has examined the characteristics of individuals and households accessing food banks, the locational or transportation accessibility aspect of food bank access is not well understood. A wealth of literature examining the food desert concept suggests that, in addition to socio-economic and demographic factors, location and transportation networks play a key role in a household's accessibility to healthy foods (Paez et al., 2010; Vanderlee and L'Abbé, 2017; Widener, 2018). For food banks specifically, previous qualitative research in Ontario by Smith-Carrier et al. (2017) has noted that "transportation can be challenging, particularly if the food bank is situated in a remote location" (p. 32). Particularly, it appears that participants experience challenges with the "inordinate amount of time necessary to obtain food, and difficulties associated with transportation" (p. 39). Users of food banks, according to this research, rely on a variety of modes of transportation to access services. Consequently, the location of facilities matters; in the words of an interviewee: "I wish it [the food bank] was a little more centrally located. Because if I didn't have a bike I'd have to walk it all the way out there and back. I wonder about people who don't" (p. 39).

To offer greater insight into the role of transportation and location in food bank accessibility, this research examines how geographic accessibility to food banks and food services changed in Hamilton during the COVID-19 pandemic.

Methods and Materials

Methods

For the research in this paper we adopt the balanced floating catchment area approach of Paez et al. (2019). This method for estimating accessibility is a form of the widely-used two-stage floating catchment area method (Luo and Wang, 2003; Radke and Mu, 2000). Floating catchment areas are used to estimate accessibility when there are potential congestion effects, and operate by calculating first the *demand* for spatially distributed services. The demand (usually the number of people who require a service) is used to calculate a level of service. In a second step, the level of service is allocated back to the population. Demand and level of service are allocated using some form of distance-decay to embody the geographical principle that, given a choice, people prefer to travel less than more when reaching destinations.

More formally, the first step of this method is as follows:

$$L_j = \frac{S_j}{\sum_{i=1}^n P_i w_{ij}}$$

where S_j is the level of supply at location j, in simplest terms whether a service point is present (i.e., $S_j = 1$) or not (i.e., $S_j = 0$); P_i is the population at location i that demands the service; and w_{ij} is a weight, typically a function of the distance between locations i and j. L_j is the level of service at location j and it is the inverse of the number of people that need to be serviced.

The second step in this process is then summing the level of service that each population unit can reach, according to the distance-decay weight:

$$A_i = \sum_{j=1}^{J} L_j w_{ji}$$

where A_i is the accessibility to the service, which is in the same units as the level of service: as the inverse of the population being serviced. When the population being serviced is low accessibility is high (i.e., there is little competition for the service), and viceversa.

Floating catchment area methods are prone to overestimation of the population and the level of service due to multiple-counting. The population at P_i is allocated to *every* service point j for which $w_{ij} > 0$. Similarly, the level of service at LOS_j is allocated to *every* population point for which $w_{ji} > 0$. This inflation effect has been known for several years, and several modifications have been proposed to mitigate it (Delamater, 2013; e.g., Wan et al., 2012). A definitive solution to this issue was presented by Paez et al. (2019). In order to avoid the multiple-counting in the summations, the population and the level of service need to be allocated *proportionally*. This is achieved by standardizing the weights as follows:

$$w_{ij}^{\text{st}} = \frac{w_{ij}}{\sum_{i=1}^{n} w_{ij}}$$

and:

$$w_{ji}^{\text{st}} = \frac{w_{ji}}{\sum_{j=1}^{J} w_{ji}}$$

The standardized weights satisfy the following conditions:

$$\sum_{i=1}^{n} w_{ij}^{\text{st}} = 1$$

and:

$$\sum_{j=1}^{J} w_{ji}^{\text{st}} = 1$$

Since the population is allocated proportionally, its value is preserved:

$$\sum_{i=1}^{n} P_i w_{ij}^{\text{st}} = P_i$$

as is the level of service:

$$\sum_{j=1}^{J} L_j w_{ji}^{\text{st}} = L_j$$

Study Area

Need to provide some context here: the geography which makes transportation challenging, i.e., due to the escarpment; the main

parts of the city: city core, inner suburbs, industrial north, suburban, exurban; and the industrial background of the city maybe, with poverty rates compared to other Canadian cities?

Data

Data have been prepared for sharing as a data package[6]. The contents of the data package are described next.

Statistics Canada

Population and income statistics for 2016 were retrieved at the level of Dissemination Areas (DAs) using the package `cancensus` (von Bergmann et al., 2021). DAs are the smallest publicly available census geography in Canada. Income data corresponds to the count of households by different total income groupings.

Origins: Residential parcels

We converted all recorded residential land parcels in the City of Hamilton to points on the road network. Each point includes information about the number of residential units in the parcel. Next, we define low-income households as those having a total income of less than CAD40,000, which is approximately the mid-point of the low income cut-off (LICOs) for families in Canadian cities with populations greater than 500,000 in 2016, to match other Census data (Statistics Canada, 2020b). We then "populate" each residential unit with the probability of being a low-income household based on the counts of households by income groups in the DA in which the parcel is located. While this method assumes a constant probability of low-income household status for all residential units in a DA, the parcel-level analysis affords a high level of spatial disaggregation for the accessibility analysis.

Destinations: Food Banks and Food Service Locations

The locations of food banks and related food services were obtained from the Hamilton Public Library's Food Access Guide[7]. The guide was updated in April of 2021 to indicate any change affected on the services due to the pandemic. This includes modified business hours, a need to make reservations before frequenting, and locations that have completely shut down in consequence. While some food bank services have a specific a target population, such as prioritizing family with young children aged between 0 and 3 or accepting only those providing proof of low-income status through housing and utility statements, all the food bank services indicated below are designed to accommodate those in need of food at zero to low cost. With our focus on food banks and food services that offer free or low-cost meals at particular locations, we first removed services such as Meals on Wheels and other food access services such as food box, community kitchens,

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[6]add repository
[7]http://foodaccessguide.ca/sites/default/files/partnersites/pdf/foodaccessguide.pdf

Table 1: foodbank and Food Service Information.

Type	Description	Locations Pre-COVID	Locations During COVID	Additional Notes
Congregate Dining	Congregate and dining programs provide low-cost meals that are enjoyed in a community setting. Transportation may be provided	7	2	One remaining location reduced hours during COVID
Community Meals	Programs often run by volunteers that organize suppers, lunches or other get-togethers that give community residents an opportunity to meet one another in a friendly and informal atmosphere while sharing a meal	11	9	NA
Food Banks	Food Banks and Emergency Food programs provide individuals and families with grocery items free of charge	27	26	One remaining location reduced hours during COVID while 4 others moved to appointment only
Free Meals	Meals are provided free of charge in the community through volunteer labour and donations	9	5	One remaining location reduced hours during COVID
Low-Cost Meals	Restaurants, cafeterias and other eating establishments operated by hospitals, senior centers or other organizations which provide reduced-cost meals for low-income people, older adults or other targeted individuals.	2	1	The remaining location reduced hours during COVID

student nutrition programs, and shopping and transportation. In addition, two free meal services held on different days at the same location were collapsed into a single service point for the accessibility analysis. Additional details on the operations of individual facilities is not publicly available, and with the changes in operations it proved unfeasible to collect it. For this reason, the analysis to follow is of accessibility to the location of food banks and services, but not to specific services (e.g., breakfasts vs. food boxes).

Routing and travel time tables

Travel time tables for three modes (car, transit, walking) were computed using the parcels as the origins and the locations of the food banks as the destinations. For routing, the package `r5r` (Pereira et al., 2021b) was used with a network extract for the City of Hamilton from OpenStreetMaps and the General Transit Feed Specification from Hamilton Street Railway, the local transit operator. For routing purposes we used maximum values of 180 min and 10,000 m walking distance: any destination that exceeded these thresholds was ignored. The departure time used for routing was **TIME**.

Transportation Tomorrow Survey

We used the Data Retrieval System of the Transportation Tomorrow Survey (TTS)[8] to download cross-tabulations of: 1) primary mode of travel per trip by income by place of residence; and 2) age by income by place of residence. These data are from the 2016 Survey (the most recent available), and data are geocoded at the level of Traffic Analysis Zones (TAZ) using the most recent

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[8]http://dmg.utoronto.ca/

zoning system from 2006. Each parcel point is populated with the proportion of trips by three modes of travel: car (as driver or passenger), transit, and walk.

Expected Travel Times

Once we obtained travel time tables with population (number of households) and proportion of trips by mode, we calculated the expected travel time *ett* from each parcel i to a food bank or food service location j as follows:

$$ett_{ij} = p_i^c \cdot tt_{ij}^c + p_i^t \cdot tt_{ij}^t + p_i^w \cdot tt_{ij}^w$$

where p_i^k is the proportion of trips by mode k in the TAZ of parcel i, and tt_{ij}^k is the travel time from parcel i to the food bank. In other words, the expected travel time is the weighted sum of travel times to the food bank, with the weights given by the expected modal split in the TAZ.

Results and Discussion

Figure 1 shows the location of food banks and services in the City of Hamilton and their status. Before the pandemic there were 58 of which 14 (24.14%) closed during the pandemic. As shown in the figure, food services tend to be predominantly located in the central parts of the city. This is not surprising: population density is high there, and it is also the part of the city where lower income households are more numerous in absolute and relative terms (see Figure 2). Alas, this is also the part of the city where most of the closures during the pandemic happened.

To implement the accessibility calculations, we must select a distance-decay function. In this task we find limited support in the literature, which is mostly silent on the travel patterns of people who visit food banks. For this reason, we opt for a simple cumulative opportunities function as follows:

$$w_{ij} = w_{ji} = \begin{cases} 1 & \text{if } ett_{ij} \leq \delta \\ 0 & \text{otherwise} \end{cases}$$

where ett_{ij} is the multimodal expected travel time as described previously, and δ is a travel threshold. When the expected travel time exceeds this threshold, a facility is no longer considered accessible. Moreover, the weights are standardized for the balanced floating catchment area approach.

Figure 3 shows the results of conducting sensitivity analysis of the system-wide accessibility as we vary the threshold (considering the situation before the pandemic). There is a clear pattern whereby more strict values of δ are associated with higher levels of system-wide accessibility: while increases in accessibility that result from decreases in the travel time window might seem counter-intuitive, this is a result of lower *congestion*, since fewer households are serviced and thus competition for the same resources is more limited. System-wide accessibility declines with higher values of δ: as more households are serviced, congestion grows and the level of service declines, although this happens
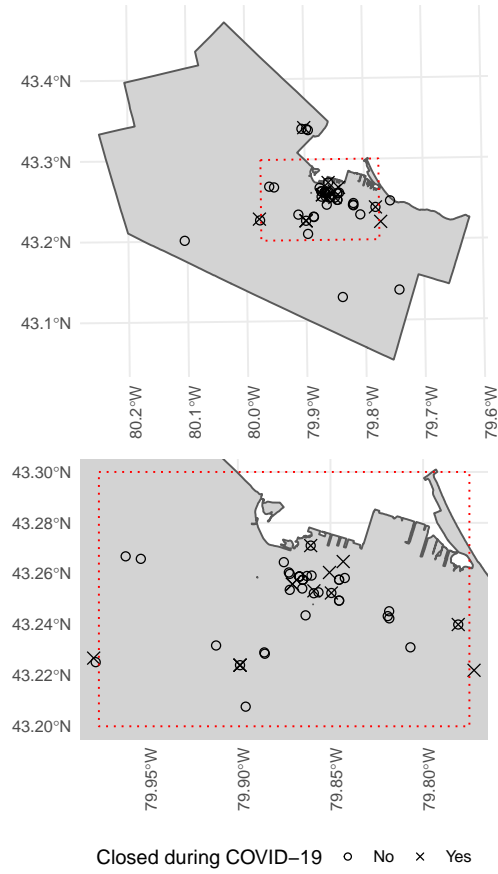
Figure 1: Location of food banks/services and operation status; the dotted box is an inset of the central part of the City of Hamilton
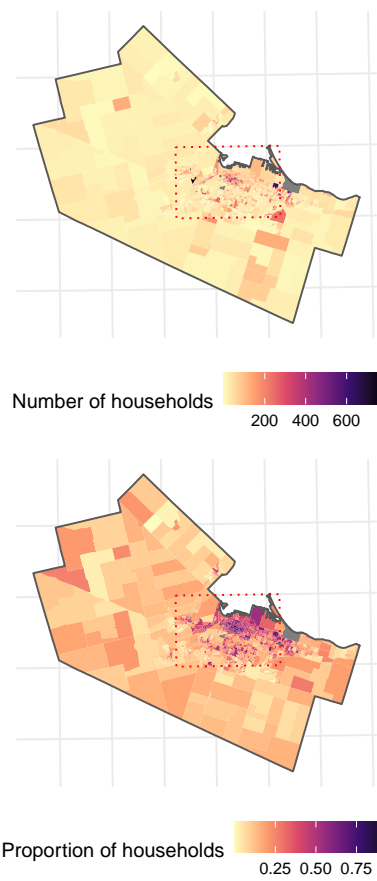
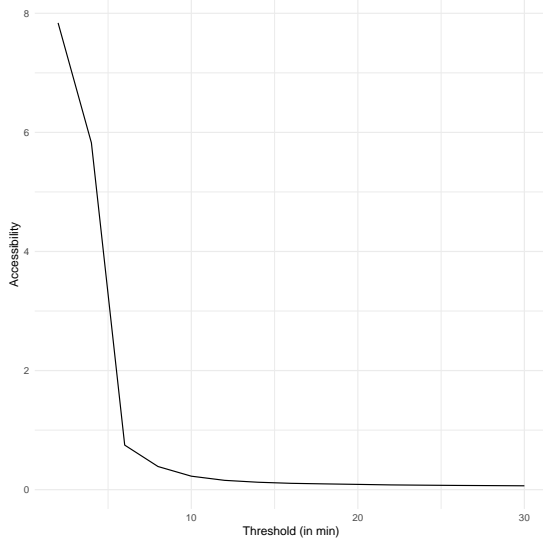Figure 2: Number and proportion of households with incomes less than CAD40,000.

Figure 3: Accessibility as a function of threshold

at a declining rate. We are not aware of any research that explain how long people are expected to travel for food banks, but we note that in developing countries, access to drinking water is defined as a source that takes less than 30 minutes to reach (round trip, see UNICEF-WHO, 2019). There is no reason why people in affluent countries should be expected to travel more for a basic need such as food. Accordingly, we adopt a 15-minute threshold for the analysis (representing a one-way trip). This threshold is also approximately where the rate of change in accessibility slows down.

Using the 15-minute threshold, we find that the system-wide accessibility (interpreted as a provider-to-population ratio) was 0.065 (food banks/service locations per low income household in the city) before COVID-19, but declined to 0.037 during the pandemic. It is striking that although almost 76% of food facilities remained in operation during the pandemic, there was a loss of accessibility greater than 43%, suggesting the location of food banks and related services plays an important role in serving those in need.

Turning to the location of individual facilities, the levels of service offered before and during the pandemic are shown in Figure 4. The level of service is functionally the inverse of the number of low-income households in the travel-mode weighted travel time catchment area of the facilities (this is because $S_j = 1 \forall j$, i.e., each location represents a "capacity" of 1). Higher values mean that a facility is expected to service fewer households. Conversely, lower values indicate grater congestion.

The general pattern of the levels of service is similar before and during the pandemic, with lower values in the center of the city. Three more peripheral facilities towards the south of the city also have lower levels of service, presum-

ably because they are expected to service relatively large suburban/exurban populations. During the pandemic, however, the levels of service dropped, in some cases quite substantially. The pattern of the losses in level of service, moreover, is not uniform. The upper pane of Figure 5 shows that the three peripheral facilities in the southern suburban/exurban part of the city had low levels of service to begin with, but did not see major declines during the pandemic. Further, the inset map shows that the levels of service deteriorated more in the central part of the city. However, the loss of level of service was not as large in the core (where most of the food banks/services are found), but instead was more marked in the inner ring around the core, where facilities may have faced greater demand from both central city and suburban populations after the closure of food banks during the pandemic.

To further elucidate this issue, we now turn to the results of the accessibility analysis. As with the level of service of individual facilities, the general pattern of accessibility before and during the pandemic is similar. Figure 6 reveals that, compared with the outer rural zones, the more urban zones of the city generally exhibit higher accessibility to food banks and food service locations. However, the pattern is not particularly smooth - this is largely attributable to the weighting of travel times by mode of transportation according to the trip patterns of low-income household respondents according to the TTS. For example, in zones where low-income households make a high proportion of trips by walking, access to food bank locations by walking is afforded a concomitantly high weight in our calculations of travel time compared to transit or car travel. From this, highly-accessible locations result from a mix of characteristics: low-income households in locations where travel options that align with zonal modal split are available to connect them to food bank locations with high levels of service within 15 minutes. This seems to track with the experience of some users of these services, as reported by Smith-Carrier et al. (2017).

We find that the accessibility landscape deteriorated substantially during the pandemic, with accessibility dropping on average by almost 41%, but with large variations: some zones experienced changes in accessibility of only about 10%, whereas the most affected zone saw a loss of accessibility of almost 71%. Figure 7 shows the changes in accessibility. Every zone is worse off after the closure of facilities during the pandemic, but some parts of the city seem to have been particularly affected. We used a local indicator of spatial autocorrelation (Anselin, 1995) to explore the pattern of change in accessibility. Twenty-four TAZ are flagged as having significant large losses of accessibility (at $p <= 0.10$, without correcting for multiple comparisons). Those zones are highlighted in the figure, where it can be seen that they form more or less compact neighborhoods. Remarkably, the largest (and significant) drops in accessibility are not downtown, but located in two cases in the industrial north of the city, in one case in an inner suburb above the escarpment (**need to describe the study area!**), and lastly in a more suburban/exurban region in the south-west (**share other insights about these regions, maybe based on weighted travel patterns?**).

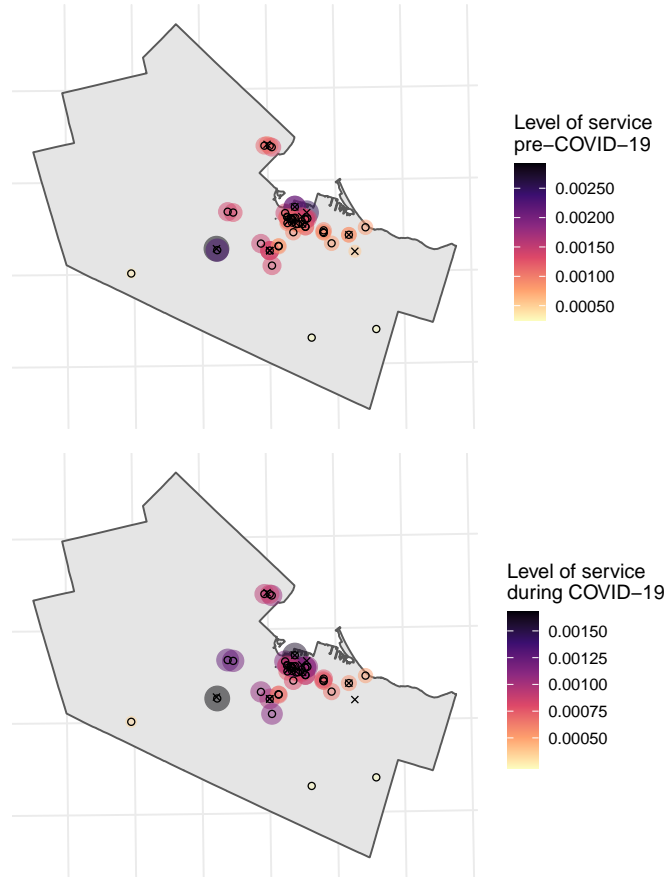Discuss the results of aggregating the accessibility by age group (see Table

Figure 4: Levels of service at each facility pre-COVID-19 (top panel) and during COVID-19 (bottom panel).
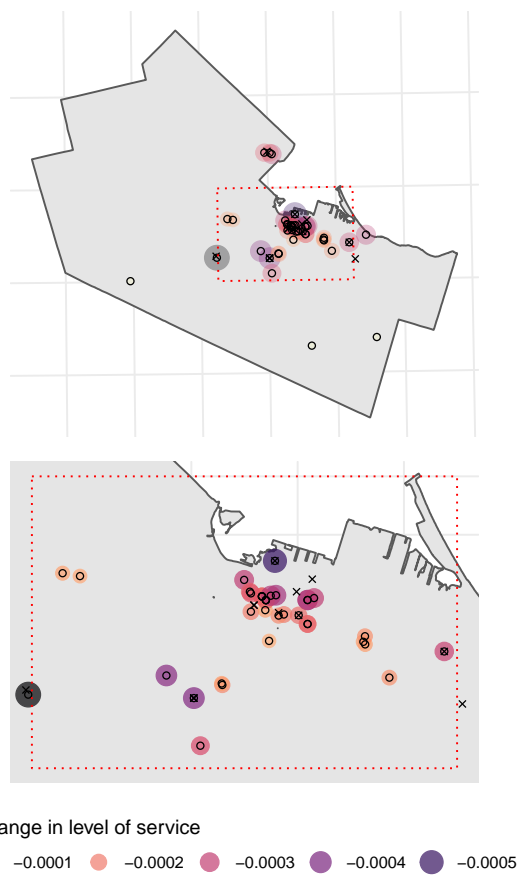
Figure 5: Changes in levels of service at each facility from pre-COVID-19 to during COVID-19.
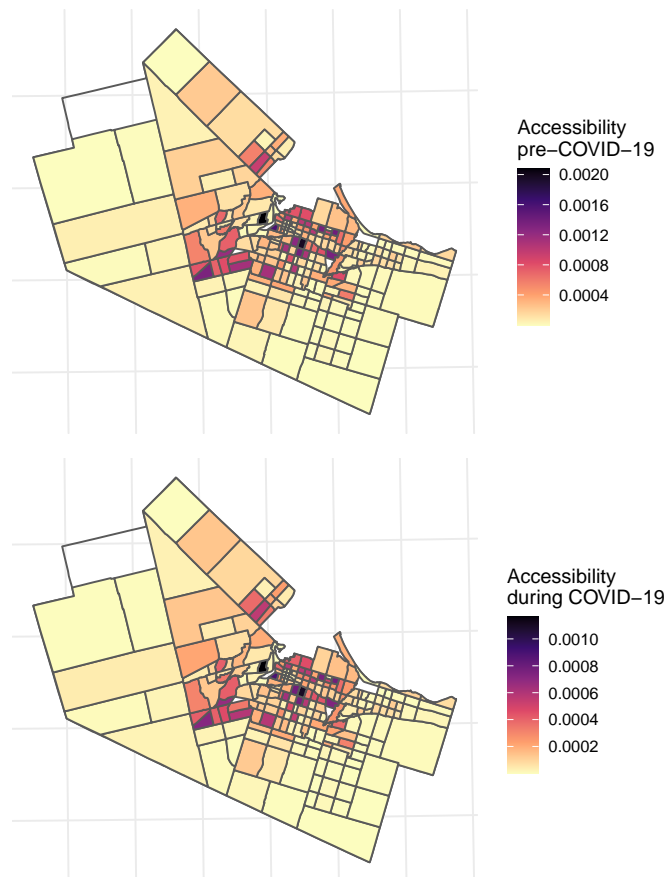
Figure 6: Accessibility by traffic analysis zone pre-COVID-19 (top panel) and during COVID-19 (bottom panel).
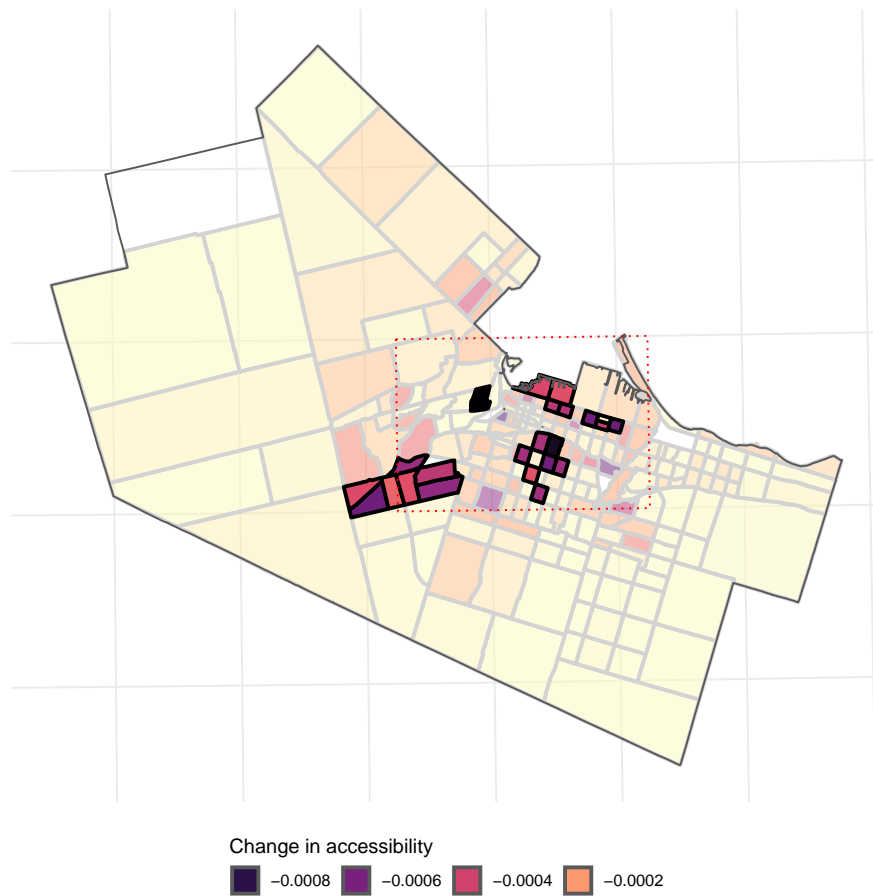
Figure 7: Changes in accessibility from pre-COVID-19 to during COVID-19. Highlighted areas had significantly large changes in accessibility according to Local Moran's I.

Table 2: Accessibility by age group among members households with incomes less than CAD40,000.

Population			Accessibility		
Children (age ≤ 18)	Adults (19-64)	Seniors (age ≥ 65)	Before COVID-19	During COVID-19	Difference
3,445 (25%)	11,860 (24.8%)	6,584 (25.9%)	0.00229	0.00173	-0.00057
4,477 (32.4%)	12,838 (26.9%)	6,847 (27%)	0.00707	0.00418	-0.00289
3,541 (25.7%)	13,189 (27.6%)	7,020 (27.6%)	0.01580	0.00911	-0.00669
2,340 (17%)	9,918 (20.7%)	4,940 (19.5%)	0.03985	0.02202	-0.01783

Note:

Population values have been rounded

2). Follow with the analysis of hours of travel?

Conclusions

LIMITATIONS
Words go here.

References

Anselin, L., 1995. Local indicators of spatial association - LISA. Geographical Analysis 27, 93–115.

Bazerghi, C., McKay, F.H., Dunn, M., 2016. The role of food banks in addressing food insecurity: A systematic review. Journal of community health 41, 732–740.

Bhattacharya, J., Currie, J., Haider, S., 2004. Poverty, food insecurity, and nutritional outcomes in children and adults. Journal of health economics 23, 839–862. doi:https://doi.org/10.1016/j.jhealeco.2003.12.008

Black, J.L., Seto, D., 2020. Examining patterns of food bank use over twenty-five years in vancouver, canada. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations 31, 853–869. doi:https://doi.org/10.1007/s11266-018-0039-2

Boucher, B.A., Manafò, E., Boddy, M.R., Roblin, L., Truscott, R., 2017. The ontario food and nutrition strategy: Identifying indicators of food access and food literacy for early monitoring of the food environment. Health promotion and chronic disease prevention in Canada : research, policy and practice 37, 313–319. doi:10.24095/hpcdp.37.9.06

Brunsdon, C., Comber, A., 2020. Opening practice: Supporting reproducibility and critical spatial data science. Journal of Geographical Systems 1–20. doi:10.1007/s10109-020-00334-2

Delamater, P.L., 2013. Spatial accessibility in suboptimally configured health care systems: A modified two-step floating catchment area (M2SFCA) metric. Health & Place 24, 30–43. doi:10.1016/j.healthplace.2013.07.012

DeWeese, J., Hawa, L., Demyk, H., Davey, Z., Belikow, A., El-geneidy, A., 2020. A tale of 40 cities: A preliminary analysis of equity impacts of COVID-19 service adjustments across north america. Findings. doi:10.32866/001c.13395

Elgar, F.J., Pickett, W., Pförtner, T.-K., Gariépy, G., Gordon, D., Georgiades, K., Davison, C., Hammami, N., MacNeil, A.H., Da Silva, M.A., others, 2021. Relative food insecurity, mental health and wellbeing in 160 countries. Social Science & Medicine 268, 113556. doi:https://doi.org/10.1016/j.socscimed.2020.113556

Enns, A., Rizvi, A., Quinn, S., Kristjansson, E., 2020. Experiences of food bank access and food insecurity in ottawa, canada. Journal of Hunger & Environmental Nutrition 15, 456–472. doi:https://doi.org/10.1080/19320248.2020.1761502

Gundersen, C., Tarasuk, V., Cheng, J., De Oliveira, C., Kurdyak, P., 2018. Food insecurity status and mortality among adults in ontario, canada. PloS one 13, e0202642.

Holmes, E., Black, J.L., Heckelman, A., Lear, S.A., Seto, D., Fowokan, A., Wittman, H., 2018. "Nothing is going to change three months from now": A mixed methods characterization of food bank use in greater vancouver. Social Science & Medicine 200, 129–136. doi:https://doi.org/10.1016/j.socscimed.2018.01.029

Jones, A.D., 2017. Food insecurity and mental health status: A global analysis of 149 countries. American journal of preventive medicine 53, 264–273. doi:https://doi.org/10.1016/j.amepre.2017.04.008

Kirkpatrick, S.I., Tarasuk, V., 2008. Food insecurity is associated with nutrient inadequacies among canadian adults and adolescents. The Journal of nutrition 138, 604–612. doi:https://doi.org/10.1093/jn/138.7.1399

Laborde, D., Martin, W., Vos, R., 2020. Poverty and food insecurity could grow dramatically as COVID-19 spreads. International Food Policy Research Institute (IFPRI), Washington, DC.

Loopstra, R., Tarasuk, V., 2012. The relationship between food banks and household food insecurity among low-income toronto families. Canadian Public Policy 38, 497–514. doi:10.3138/cpp.38.4.497

Lovelace, R., 2021. Open source tools for geographic analysis in transport planning. Journal of Geographical Systems. doi:10.1007/s10109-020-00342-2

Luo, W., Wang, F.H., 2003. Measures of spatial accessibility to health care in a GIS environment: Synthesis and a case study in the chicago region. Environment and Planning B-Planning & Design 30, 865–884.

McKay, F.H., Bastian, A., Lindberg, R., 2021. Exploring the response of the victorian emergency and community food sector to the COVID-19 pandemic. Journal of Hunger & Environmental Nutrition 1–15. doi:10.1080/19320248.2021.1900974

Men, F., Tarasuk, V., 2021. Food insecurity amid the COVID-19 pandemic: Food charity, government assistance and employment. Canadian Public Policy COVID-19, e2021001. doi:10.3138/cpp.2021-001

Niles, M.T., Bertmann, F., Belarmino, E.H., Wentworth, T., Biehl, E., Neff, R., 2020. The early food insecurity impacts of COVID-19. Nutrients 12, 2096.

Olson, C.M., 1999. Nutrition and health outcomes associated with food insecurity and hunger. The Journal of nutrition 129, 521S–524S. doi:https://doi.org/10.1093/jn/129.2.521S

Paez, A., Higgins, C.D., Vivona, S.F., 2019. Demand and level of service inflation in floating catchment area (FCA) methods. PloS one 14, e0218773. doi:10.1371/journal.pone.0218773

Paez, A., Mercado, R.G., Farber, S., Morency, C., Roorda, M., 2010. Relative accessibility deprivation indicators for urban settings: Definitions and application to food deserts in montreal. Urban Studies 47, 1415–1438. doi:10.1177/0042098009353626

Páez, A., Scott, D.M., Morency, C., 2012. Measuring accessibility: Positive and normative implementations of various accessibility indicators. Journal of Transport Geography 25, 141–153. doi:https://doi.org/10.1016/j.jtrangeo.2012.03.016

Pereira, R.H.M., Braga, C.K.V., Servo, L.M., Serra, B., Amaral, P., Gouveia, N., Paez, A., 2021a. Geographic access to COVID-19 healthcare in brazil using a balanced float catchment area approach. Social Science & Medicine 273, 113773. doi:https://doi.org/10.1016/j.socscimed.2021.113773

Pereira, R.H.M., Saraiva, M., Herszenhut, D., Braga, C.K.V., Conway, M.W., 2021b. r5r: Rapid realistic routing on multimodal transport networks with r^5 in r. Findings. doi:10.32866/001c.21262

Radke, J., Mu, L., 2000. Spatial decomposition, modeling and mapping service regions to predict access to social programs. Annals of Geographic Information Sciences 6, 105–112.

Ramsey, R., Giskes, K., Turrell, G., Gallegos, D., 2011. Food insecurity among australian children: Potential determinants, health and developmental consequences. Journal of Child Health Care 15, 401–416. doi:https://doi.org/10.1177%2F1367493511423854

Riches, G., 2002. Food banks and food security: Welfare reform, human rights and social policy. Lessons from canada? Social Policy & Administration 36, 648–663.

Seligman, H.K., Laraia, B.A., Kushel, M.B., 2010. Food insecurity is associated with chronic disease among low-income NHANES participants. The Journal of nutrition 140, 304–310.

Smith-Carrier, T., Ross, K., Kirkham, J., Decker Pierce, B., 2017. 'Food is a right... nobody should be starving on our streets': Perceptions of food bank usage in a mid-sized city in ontario, canada. Journal of Human Rights Practice 9, 29–49.

Statistics Canada, 2020a. Food insecurity during the COVID-19 pandemic (No. Catalogue no. 45280001).

Statistics Canada, 2020b. Table 11-10-0241-01 low income cut-offs (LICOs) before and after tax by community size and family size, in current dollars. doi:https://doi.org/10.25318/1110024101-eng

Stuff, J.E., Casey, P.H., Szeto, K.L., Gossett, J.M., Robbins, J.M., Simpson, P.M., Connell, C., Bogle, M.L., 2004. Household food insecurity is associated with adult health status. The Journal of nutrition 134, 2330–2335. doi:Oxford University Press

Tarasuk, V., Dachner, N., Loopstra, R., 2014. Food banks, welfare, and food insecurity in canada. British Food Journal.

Tarasuk, V., Fafard St-Germain, A.-A., Loopstra, R., 2020. The relationship between food banks and food insecurity: Insights from canada. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations 31, 841–852. doi:10.1007/s11266-019-00092-w

Tarasuk, V., Fafard St-Germain, A.-A., Mitchell, A., 2019. Geographic and socio-demographic predictors of household food insecurity in canada, 2011–12. BMC Public Health 19, 12. doi:10.1186/s12889-018-6344-2

Tarasuk, V., Vogt, J., 2009. Household food insecurity in ontario. Canadian Journal of Public Health 100, 184–188. doi:10.1007/BF03405537

UNICEF-WHO, 2019. Progress on household drinking water, sanitation and hygiene 2000–2017. Special focus on inequalities.

Vanderlee, L., L'Abbé, M., 2017. Food for thought on food environments in canada. Health promotion and chronic disease prevention in Canada : research, policy and practice 37, 263–265. doi:10.24095/hpcdp.37.9.01

von Bergmann, J., Shkolnik, D., Jacobs, A., 2021. Cancensus: R package to access, retrieve, and work with canadian census data and geography.

Wakefield, S., Fleming, J., Klassen, C., Skinner, A., 2013. Sweet charity, revisited: Organizational responses to food insecurity in hamilton and toronto, canada. Critical Social Policy 33, 427–450.

Wan, N., Zou, B., Sternberg, T., 2012. A three-step floating catchment area method for analyzing spatial access to health services. International Journal of Geographical Information Science 26, 1073–1089. doi:10.1080/13658816.2011.624987

Widener, M.J., 2018. Spatial access to food: Retiring the food desert metaphor. Physiology & behavior 193, 257–260. doi:https://doi.org/10.1016/j.physbeh.2018.02.032

Wolfson, J.A., Leung, C.W., 2020. Food insecurity and COVID-19: Disparities in early effects for US adults. Nutrients 12, 1648.